

The Effect of Body Composition on Pulmonary Function

Jung Eun Park, M.D., Jin Hong Chung, M.D., Kwan Ho Lee, M.D., Kyeong Cheol Shin, M.D.

Department of Internal Medicine, Regional Center for Respiratory Disease, Yeungnam University Medical Center, Yeungnam University College of Medicine, Daegu, Korea

Background: The pulmonary function test is the most basic test method to diagnosis lung disease. The purpose of this study was to research the correlation of the body mass index (BMI), the fat percentage of the body mass (fat%), the muscle mass, the fat-free mass (FFM) and the fat-free mass index (FFMI), waist-hip ratio (WHR), on the forced expiratory volume curve.

Methods: Between March and April 2009, a total of 291 subjects were enrolled. There were 152 men and 139 female (mean age, 46.3 ± 9.92 years), and they were measured for the following: forced vital capacity (FVC), forced expiratory volume at 1 second (FEV_1), and forced expiratory flow during the middle half of the FVC (FEF_{25-75}) from the forced expiratory volume curve by the spirometry, and the body composition by the bioelectrical impedance method. Correlation and a multiple linear regression, between the body composition and pulmonary function, were used.

Results: BMI and fat% had no correlation with FVC, FEV_1 in male, but FFMI showed a positive correlation. In contrast, BMI and fat% had correlation with FVC, FEV_1 in female, but FFMI showed no correlation. Both male and female, FVC and FEV_1 had a negative correlation with WHR (male, FVC $r = -0.327$, FEV_1 $r = -0.36$; $p < 0.05$; female, FVC $r = -0.175$, FEV_1 $r = -0.213$; $p < 0.05$). In a multiple linear regression of considering the body composition of the total group, FVC explained FFM, BMI, and FFMI in order ($r^2 = 0.579, 0.657, 0.663$). FEV_1 was explained only fat% ($r^2 = 0.011$), and FEF_{25-75} was explained muscle mass, FFMI, FFM ($r^2 = 0.126, 0.138, 0.148$).

Conclusion: The BMI, fat%, muscle mass, FFM, FFMI, WHR have significant association with pulmonary function but r^2 (adjusted coefficient of determination) were not high enough for explaining lung function.

Key Words: Pulmonary Function Tests; Body Composition; Factor Analysis, Statistical

Introduction

Pulmonary function test is one of the basic and essential tests for diagnosis and assessment of pulmonary diseases such as pulmonary dysfunction, chronic obstructive pulmonary disease (COPD) and asthma^{1,2}. Factors affecting pulmonary functions include age, body weight and height, and gender. Since those factors are significantly associated with pulmonary functions, they

are used for equation of regression calculating predicted normal values of pulmonary functions test. Correlation between body composition such as body mass index (BMI), waist measure, fat mass and pulmonary functions has been studied since later 1950s. However, study results of correlation between pulmonary functions and body composition have been different from each other. In addition, since the mechanism of body composition affecting pulmonary functions has not been fully understood, body composition is not used as a factor for equation predicting pulmonary function^{2,3}.

According to Maiolo et al.⁴, correlation between forced vital capacity (FVC) and BMI, waist measurement and fat mass is more significant than that between forced expiratory volume at 1 second (FEV_1) and BMI, waist measurement and fat mass. Fat accumulation in

Address for correspondence: Jin Hong Chung, M.D.

Department of Internal Medicine, Yeungnam University Hospital, 170, Hyeonchung-ro, Nam-gu, Daegu 705-717, Korea

Phone: 82-53-620-3840, Fax: 82-53-654-8386

E-mail: jhchn@med.yu.ac.kr

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thoracic and abdominal cavities arise changes in respiratory function including sluggish thoracic movements and pulmonary compliance in thoracic cavity, reduced inspiratory capacity and falling of diaphragm⁴. Waist-hip ratio (WHR) which is associated with body fat distribution also has a correlation with pulmonary function⁵. Compared with females who usually have an intensive peripheral fat distribution, central obesity is common in males. As a result, difference in correlation according to changes in body composition is larger in males than in females⁶.

Fat free mass (FFM) is mainly composed of muscles, and is associated with physical activities and accordingly, pulmonary function can be enhanced through physical efforts⁷. As a result of a large-scale study on the correlation between hand grip strength, and FVC and FEV₁, a significant positive correlation was confirmed. This means that FFM can independently affect respiratory muscles regardless of physical activities⁸. Low FFM reduces FEV₁, and reflects reduction in respiratory muscle mass⁵. FFM index and FFM/height² (fat-free mass index [FFMI]) are values calculating FFM based on the consideration of body size.

In the present study, we confirmed whether use of values of body composition and fat distribution in the body in addition to factors such as age, body weight, height and gender is useful or not for predicting results of pulmonary function test, and investigated effects body composition and fat distribution on pulmonary function.

Materials and Methods

1. Subjects

Males and females in their 20s through 70s of age who underwent pulmonary function tests and body composition analysis (BCA) at Yeungnam University Hospital Health Promotion Center between April 2009 and June 2009 participated in the present study. Excluding candidates who have history of hypertension, diabetes, malignant tumor, heart diseases and respiratory diseases such as acute respiratory infection, tuber-

culosis, COPD, asthma, pulmonary fibrosis, bronchiectasis, and pleural diseases, a total of 291 subjects were finally selected for the present study. Numbers of male and female subjects were 152 and 139, respectively, with a mean age of 46.

2. Methods

Pulmonary function test was conducted by measuring FVC, FEV₁ and mean forced expiratory flow during the middle half of the FVC (FEF₂₅₋₇₅) at a forced expiratory curve using a spirometry (Vmax 229; Sensor Medics, Yorba Linda, CA, USA).

Through a bioelectrical impedance method using Inbody 2.0 (Biopass, Seoul, Korea), body composition values including body weight, height, BMI (kg/m²), body fat percentage (fat percentage, fat%, %), muscle mass (kg), FFM (kg), FFMI (FFM/height²) and WHR were measured.

3. Statistical processing

SPSS version 18.0 (SPSS Inc., Chicago, IL, USA) was used for statistical processing. Difference according to gender was investigated using unpaired independent t-test. In order to find out correlation between pulmonary function and body composition factors, mainly FVC, FEV₁ and FEF₂₅₋₇₅ were used. In addition, effects of body composition factors on pulmonary function were investigated using multiple linear regression. In order for correcting mutual functions among body composition factors, the factors which are highly associated with the result of pulmonary function test were investigated using stepwise selection upon consideration of multicollinearity in multiple linear regression and then, prediction on pulmonary functions test was indirectly calculated using body composition factors. Regresiveness was expressed using adjusted coefficient of determination r^2 . Statistical significance level was set at less than 0.05.

Results

Mean age of the subjects was 46.3, and means of

height and body weight were 1.64 m and 63.2 kg, respectively. No significant difference in age, WHR and FEV₁ was found between males and females. Among body composition factors, females showed significantly higher level only in body fat percentage than males, while males showed higher levels in all the remaining factors such as muscle mass, FFM and FFMI ($p < 0.05$) (Table 1).

In both males and females, FVC showed positive correlations with age, gender and BCA, and negative corre-

lations with age, body fat percentage and WHR. FEV₁ showed significant negative correlations with age and body fat percentage. FEF₂₅₋₇₅ showed correlations with BCA excluding BMI, and like FVC, showed negative correlations with age, body fat percentage. Therefore, factors associated with all of FVC, FEV₁, and FEF₂₅₋₇₅ were age and body fat percentage, and in cases of elderly subjects or higher body fat percentage, values of pulmonary function test results were lower showing negative correlations (Table 2).

Table 1. Characteristics of the study group

	Total (n=291)	Male (n=152)	Female (n=139)	p-value*
Age, yr	46.3±9.92	46.8±10.08	45.8±9.87	0.381
Height, m	1.64±0.08	1.7±0.05	1.58±0.05	0.000
Body weight, kg	63.2±10.81	69.1±10.22	56.9±7.38	0.000
BMI, kg/m ²	23.3±3.05	23.8±3.06	22.7±2.94	0.002
Fat, %	26.5±6.95	22.3±5.48	30.9±5.46	0.000
Muscle, kg	43.7±8.68	50.5±5.62	36.5±4.66	0.000
FFM, kg	46.5±8.78	53.4±5.97	39.0±3.94	0.000
FFMI, kg/m ²	17.0±2.01	18.4±1.56	15.6±1.31	0.000
Waist-hip ratio	0.929±0.54	0.897±0.03	0.965±0.78	0.305
FVC, L	3.56±0.81	4.12±0.63	2.94±0.46	0.000
FEV ₁ , L	4.31±23.10	5.95±31.9	2.51±0.41	0.187
FEF ₂₅₋₇₅ , L	3.32±1.09	3.57±1.22	3.02±0.84	0.000

Values are mean±SD.

*Independent t-test between male and female, $p < 0.05$.

BMI: body mass index; Fat, %: fat percentage of body mass; FFM: free fat mass; FFMI: free fat mass index; FVC: forced vital capacity; FEV₁: forced expiratory volume at 1 second; FEF₂₅₋₇₅: mean forced expiratory flow during the middle half of the FVC.

Table 2. Inter-correlations between the variables (total, n=291)

	FVC		FEV ₁		FEF ₂₅₋₇₅	
	r-value*	p-value	r-value*	p-value	r-value*	p-value
Age	-0.299 [†]	0.000	-0.104 [†]	0.038	-0.485 [†]	0.000
Height	0.783 [†]	0.000	0.027	0.326	0.376 [†]	0.000
Body weight	0.532 [†]	0.000	0.006	0.462	0.292 [†]	0.000
Sex	0.725 [†]	0.000	0.074	0.103	0.252 [†]	0.000
BMI	0.107 [†]	0.031	-0.019	0.372	0.095	0.072
Fat, %	-0.559 [†]	0.000	-0.12 [†]	0.02	-0.187 [†]	0.000
Muscle, kg	0.745 [†]	0.000	0.057	0.166	0.356 [†]	0.000
FFM, kg	0.761 [†]	0.000	0.057	0.167	0.353 [†]	0.000
FFMI, kg/m ²	0.574 [†]	0.000	0.074	0.107	0.250 [†]	0.000
Waist-hip ratio	-0.123 [†]	0.018	-0.013	0.414	-0.118 [†]	0.022

*Correlation coefficient. [†] $p < 0.05$.

FVC: forced vital capacity; FEV₁: forced expiratory volume at 1 second; FEF₂₅₋₇₅: mean forced expiratory flow during the middle half of the FVC; BMI: body mass index; Fat, %: fat percentage of body mass; FFM: free fat mass; FFMI: free fat mass index.

In case of male, no significant correlations with FVC, BMI, and body fat percentage were found. Instead, positive correlations with muscle indexes such as muscle mass, FFM, and FFMI were found while significant negative correlations with WHR which is an obesity index were found. Both FEV₁ and FEF₂₅₋₇₅ did not show significant correlations with BMI and body fat percentage. FEF₂₅₋₇₅ did not show a correlation with WHR, either. Accordingly, in case of male, FVC, FEV₁, and FEF₂₅₋₇₅ did not show significant correlations with BMI and body fat percentage (Table 3).

In case of female, factors associated with all of FVC,

FEV₁, and FEF₂₅₋₇₅ were age, height, BMI, body fat percentage, muscle mass, FFM and WHR, and no significant correlation was found between body weight and FFMI (Table 4).

As a result of multiple linear regression, in terms of FVC in both males and females, most statistical significance was found in FFM followed by BMI and FFMI ($p < 0.05$). Changes in FVC upon completion of correcting FFM and BMI could be explained by 66% through the changes in FFMI. In case of male, the most significance was observed in free mass followed by WHR and body fat percentage ($p < 0.05$), while in case of fe-

Table 3. Inter-correlations between the variables (male, n=152)

	FVC		FEV ₁		FEF ₂₅₋₇₅	
	r-value*	p-value	r-value*	p-value	r-value*	p-value
Age	-0.509 [†]	0.000	-0.667 [†]	0.000	-0.531 [†]	0.000
Height	0.506 [†]	0.000	0.494 [†]	0.000	0.286 [†]	0.000
Body weight	0.271 [†]	0.000	0.308 [†]	0.000	0.239 [†]	0.002
BMI	0.06	0.231	0.107	0.095	0.127	0.059
Fat, %	-0.151	0.32	-0.123	0.065	-0.012	0.441
Muscle, kg	0.446 [†]	0.000	0.476 [†]	0.000	0.317 [†]	0.000
FFM, kg	0.447 [†]	0.000	0.476 [†]	0.000	0.318 [†]	0.000
FFMI, kg/m ²	0.221 [†]	0.003	0.269 [†]	0.000	0.221 [†]	0.005
Waist-hip ratio	-0.327 [†]	0.000	-0.36 [†]	0.000	-0.221	0.003

*Correlation coefficient. [†] $p < 0.05$.

FVC: forced vital capacity; FEV₁: forced expiratory volume at 1 second; FEF₂₅₋₇₅: mean forced expiratory flow during the middle half of the FVC; BMI: body mass index; Fat, %: fat percentage of body mass; FFM: free fat mass; FFMI: free fat mass index.

Table 4. Inter-correlations between the variables (female, n=139)

	FVC		FEV ₁		FEF ₂₅₋₇₅	
	r-value*	p-value	r-value*	p-value	r-value*	p-value
Age	-0.45 [†]	0.000	-0.61 [†]	0.000	-0.495 [†]	0.000
Height	0.528 [†]	0.000	0.584 [†]	0.000	0.344 [†]	0.000
Body weight	0.129	0.065	0.086	0.156	0.075	0.189
BMI	-0.173 [†]	0.021	-0.22 [†]	0.005	-0.095	0.132
Fat, %	-0.29 [†]	0.000	-0.272 [†]	0.001	-0.115	0.089
Muscle, kg	0.316 [†]	0.000	0.28 [†]	0.000	0.194 [†]	0.011
FFM, kg	0.389 [†]	0.000	0.313 [†]	0.000	0.158 [†]	0.032
FFMI, kg/m ²	-0.002	0.492	-0.1	0.121	-0.089	0.149
Waist-hip ratio	-0.175 [†]	0.019	-0.213 [†]	0.006	-0.176 [†]	0.019

*Correlation coefficient. [†] $p < 0.05$.

FVC: forced vital capacity; FEV₁: forced expiratory volume at 1 second; FEF₂₅₋₇₅: mean forced expiratory flow during the middle half of the FVC; BMI: body mass index; Fat, %: fat percentage of body mass; FFM: free fat mass; FFMI: free fat mass index.

Table 5. Results of multiple regression analysis for the FVC including body composition (BMI, fat%, muscle, FFM, FFMI, and WHR)

		β	SE	p-value*	$r^{2\dagger}$
Total (n=291)	FFM	0,07	0,004	0,000	0,579
	BMI	-0,085	0,01	0,000	0,657
	FFMI	-0,106	0,43	0,014	0,663
Male (n=152)	FFM	0,48	0,008	0,000	0,194
	WHR	-6,796	1,239	0,000	0,325
	Fat%	0,042	0,014	0,004	0,358
Female (n=139)	FFM	0,46	0,009	0,000	0,145
	FFMI	-0,238	0,037	0,000	0,339
	Fat%	-0,013	0,006	0,037	0,355

* $p < 0,05$. \dagger Adjusted coefficient of determination.

FVC: forced vital capacity; BMI: body mass index; Fat%: fat percentage of the body mass; FFM: fat-free mass; FFMI: fat-free mass index; WHR: waist-hip ratio; β : regression coefficient; SE: standard error.

Table 6. Results of multiple regression analysis for the FEV₁ including body composition (BMI, fat%, muscle, FFM, FFMI, and WHR)

		β	SE	p-value*	$r^{2\dagger}$
Total (n=291)	Fat%	-0,399	0,194	0,041	0,011
Male (n=152)	FFM	0,05	0,007	0,000	0,222
	WHR	-7,248	1,156	0,000	0,380
	Fat%	0,062	0,013	0,000	0,462
	FFMI	0,162	0,057	0,005	0,487
Female (n=139)	FFM	0,033	0,009	0,000	0,091
	FFMI	-0,224	0,03	0,000	0,345
	WHR	-0,089	0,036	0,015	0,368

* $p < 0,05$. \dagger Adjusted coefficient of determination.

FEV₁: forced expiratory volume at 1 second; BMI: body mass index; Fat%: fat percentage of the body mass; FFM: fat-free mass; FFMI: fat-free mass index; WHR: waist-hip ratio; β : regression coefficient; SE: standard error.

male, FVC was most significantly observed in FFM followed by FFMI and body fat percentage. After correcting FFM and WHR in males, and correcting FFM and FFMI in females, changes in FVC occurred by changes in body fat percentage in males and females were 35% and 35%, respectively ($p < 0,05$) (Table 5).

In terms of FEV₁, body fat percentage was the only factor significantly associated with in both males and females. When body fat percentage increased by 1%, FEV₁ decreased by 399 mL. Most significance in male was observed in FFM followed by WHR, body fat percentage and FFMI. After these 3 were corrected, and 1 unit of FFMI was increased, FEV₁ increased by 162 mL or 48%. In case of females, most influence was ob-

served in FFM followed by FFMI and WHR. When FFM and FFMI were corrected, FEV₁ decreased by 89 mL with an increase in WHR by 0,01 (Table 6).

In terms of FEF₂₅₋₇₅, most significance in both males and females was observed in muscle mass followed by FFMI and FFM: in males, in the order of FFM, WHR and BMI, and in females, same order as in both males and females (Table 7).

Not only body composition factors, but predicted values of pulmonary function test as well as height, body weight, age and gender were obtained as significant factors ($p < 0,05$) using multiple linear regression, and progressiveness was expressed as adjusted coefficient of determination r^2 (Table 8). In addition, adjusted co-

efficients of determination of pulmonary function test prediction equation reflecting height, body weight, age and gender, and adjusted coefficients of determination

of body composition factors, and adjusted coefficients of determination including all factor were compared (Table 9).

Table 7. Results of multiple regression analysis for the FEF₂₅₋₇₅ including body composition (BMI, fat%, muscle, FFM, FFMI, and WHR)

		β	SE	p-value*	$r^{2\dagger}$
Total (n=291)	Muscle	0,045	0,007	0,000	0,126
	FFMI	-0,128	0,058	0,029	0,138
	FFM	-0,201	0,061	0,033	0,148
Male (n=152)	FFM	0,065	0,016	0,000	0,095
	WHR	-8,810	2,655	0,001	0,152
	BMI	0,392	0,086	0,000	0,251
Female (n=139)	Muscle	0,035	0,015	0,000	0,03
	FFMI	-0,164	0,0620	0,009	0,07
	FFM	0,087	0,031	0,000	0,116

*p<0,05. †Adjusted coefficient of determination.

FEF₂₅₋₇₅: mean forced expiratory flow during the middle half of the forced vital capacity; BMI: body mass index; Fat%: fat percentage of the body mass; FFM: fat-free mass; FFMI: fat-free mass index; WHR: waist-hip ratio; β : regression coefficient; SE: standard error.

Table 8. The FVC, FEV₁, and FEF₂₅₋₇₅ equation fomular by multiple linear regression analysis (stepwise method)

	Equation fomular (total, n=291)	$r^{2\dagger}$
FVC (L)	$=(-0.861)+(3.079) * \text{Height} + (-0.454) * \text{Sex} + (-0.019) * \text{Age} + (0.024) * \text{FFM} + (-0.014) * \text{Fat\%}$	0,717
FEV ₁ (L)	$=14.884 + (-0.399) * \text{Fat\%}$	0,011
FEF ₂₅₋₇₅ (L)	$=3.950 + (-0.05) * \text{Age} + (0.039) * \text{Muscle}$	0,325

*This was meant significant factors (p<0,05) among all variables, height, weight, sex, age, BMI, fat%, muscle, FFM, FFMI, and WHR. †Adjusted coefficient of determination.

FVC: forced vital capacity; FEV₁: forced expiratory volume at 1 second; FEF₂₅₋₇₅: mean forced expiratory flow during the middle half of the FVC; FFM: fat-free mass; Fat%: fat percentage of the body mass.

Table 9. The comparison of r^2 according to variables (total, n=291)

	Variables*	$r^{2\dagger}$
FVC	Height, weight, sex, age	0,655
	Height, weight, sex, age+Fat%, FFMI, WHR	0,673
	All variables †	0,682
FEV ₁	Height, weight, sex, age	0,002
	Height, weight, sex, age+Fat%, FFMI, WHR	0,003
	All variables †	0,002
FEF ₂₅₋₇₅	Height, weight, sex, age	0,147
	Height, weight, sex, age+Fat%, FFMI, WHR	0,149
	All variables †	0,148

*All variables were meant height, weight, sex, age, BMI, fat%, muscle, FFM, FFMI, and WHR. †Adjusted coefficient of determination.

†This variables were independent of p-value.

FVC: forced vital capacity; Fat%: fat percentage of the body mass; FFMI: fat-free mass index; WHR: waist-hip ratio; FEV₁: forced expiratory volume at 1 second; FEF₂₅₋₇₅: mean forced expiratory flow during the middle half of the FVC.

Discussion

Pulmonary function test is a basic and essential test for diagnosis and assessment of pulmonary dysfunction, pulmonary diseases, and treatment effects. Predicted normal values of pulmonary functions test is calculated by an equation of regression reflecting gender, age, height, and body weight due to the significant correlation with pulmonary functions test values². Since other body measures have also been reported to have correlations with the result of pulmonary functions test, studies to find an equation of regression of pulmonary functions values according to other body measures have continued¹. Among body measures, body weight and BMI are conveniently used, but they are not differentiated by fat mass or muscle mass. In addition, application to males and people with low body weight is not appropriate compared with females and overweight people. Since fat distribution in the body is not considered in body weight and BMI, studies on correlation between pulmonary function and fat distribution in the body have also been conducted these days^{6,9}.

Mengesha investigated correlations between pulmonary function and body composition in European males and females. In both males and females, age and height showed a significant correlation with FVC and FEV₁, and in case of males, FVC and FEV₁ showed correlations with body weight, body fat percentage and FFM, but in case of females, no significance was observed¹⁰. By comparison, significant correlation was observed in both males and females in the present study. In case of male, FVC and FEV₁ showed significant correlations with muscle mass and FFM, FFMI and WHR, and FEF₂₅₋₇₅ showed significant correlations with muscle mass, FFM and FFMI. In case of female similar to males, significant correlations were also observed with BMI and body fat percentage, and with a 1% increase in body fat percentage, 13 mL of FVC decreased.

In case of male, FFMI showed a positive correlation with FVC and FEV₁, which is opposite to body fat percentage. Therefore, FFMI and body fat percentage are appropriate but BMI is not because BMI is ex-

pressed as the ratio of weight to the square of height. In case of female, FFMI shows same level of reverse effects on expiratory reserve volume and inspiratory capacity and accordingly, offset effects occur. Accordingly, BMI or body fat percentage can be used, not FFMI^{2,11}. In case of male in the present study, FVC and FEV₁ did not show correlation with BMI and body fat percentage, but showed significant correlation with FFMI. In case of female, correlation was found between BMI and body fat percentage, but no significant correlation with FFMI was found. This was because FFM composed most of the body weight in males, and body fat percentage of females was higher than that of males.

In accordance with the increasing attention on obesity, studies on correlation between the results of pulmonary functions test and obesity have been conducted. In particular, correlation between waist measure and WHR were investigated. As a result, waist measure showed negative correlation with FVC and FEV₁, and with a 1 cm increase in waist measure, 13 mL and 11 mL reductions in FVC and FEV₁, respectively were observed^{12,13}. Distribution of body fat also affects pulmonary function: the larger the waist measure or WHR were meaning the more fat distribution in upper body, the less the pulmonary function was. With an increasing abdominal fat deposition, thoracic volume reduces and consequently, not only vital capacity but power of respiratory muscles decrease deteriorating mechanical efficiency of thorax. In addition, pulmonary capacity declines and as a result of shallow and rapid respirations, respiratory dead space increases, and eventually tracheal obstruction and partial atelectasis develop³. In addition, large WHR usually results in a high risk of developing visceral abdominal obesity. Levels of systemic inflammatory cells such as cytokine including leptin, C-reactive protein and fibrinogen are high in obesity cells, and systemic inflammation is considered to be associated with deteriorating pulmonary functions¹⁴. In the present study, pulmonary function and WHR in case of male were confirmed to have negative correlation. In case of male, when WHR increased by 0.01, FVC decreased by 67.9 mL, FEV₁ decreased by 72.4 mL and

FEF₂₅₋₇₅ decreased by 88.1 mL.

Multiple body composition factors were confirmed to have correlations with the results of pulmonary functions test. However, adjusted coefficient of determination was not high according to multiple linear regression excluding height, age and body weight (Tables 5~7). Pulmonary functions prediction formula was obtained using significant variables ($p < 0.05$) by conducting a stepwise method of multiple linear regression on the variables including height, body weight, age and gender (Table 8). The pulmonary functions prediction formula which took into consideration of body composition factors did not have a higher adjusted coefficient of determination than the current pulmonary functions prediction formula which took into consideration of height, age, body weight and gender only (Table 9). In other words, correlation was found but the prediction formula based on the body composition factors did not show enough explicability to replace the current pulmonary functions prediction formula.

In the present study, only FVC, FEV₁, and FEF₂₅₋₇₅ were measured and accordingly, correlations with additional pulmonary functions test values such as total lung capacity, inspiratory capacity and functional residual capacity were not described. Correlation with smoking was also not discussed. Another limitation of the present study is that the waist-hip measures were not measured but calculated at Inbody and consequently, differences may exist.

In conclusion, not only age, gender and body weight, body fat percentage, muscle mass, FFM, FFMI and WHR also affect FVC, FEV₁, and FEF₂₅₋₇₅. In order to use these factors for a pulmonary functions prediction formula, additional studies may be required in the future.

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